GOOD PRACTICE GUIDE 279

Running refrigeration plant efficiently – a cost-saving guide for owners

GOOD PRACTICE GUIDE 279

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

RUNNING REFRIGERATION PLANT EFFICIENTLY – A COST-SAVING GUIDE FOR OWNERS

This Guide is No. 279 in the Good Practice Guide Series. It explains how to ensure that your refrigeration plant runs at optimum efficiency, leading to reduced costs and increased profits, while minimising the environmental impact.

By taking up some of the many opportunities to improve efficiency, either by good maintenance or modification, you could probably cut 25% or more off your refrigeration electricity bill.

Impressive cost savings are not the only advantage of managing your refrigeration plant effectively. Better energy efficiency leads to greater reliability, meaning fewer breakdowns, less disruption and improved productivity.

You will also reduce the global warming impact resulting from the energy consumed by your refrigeration equipment, and lower the harmful environmental effects of refrigerant emissions from the plant itself.

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FOREWORD

This Guide is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices. Best Practice is a collaborative programme targeted towards energy users and decision makers in industry, the commercial and public sectors, and building sectors including housing. It comprises four inter-related elements identified by colour-coded strips for easy reference:

— *Energy Consumption Guides:* (blue) energy consumption data to enable users to establish their relative energy efficiency performance;

— *Good Practice Guides:* (red) and *Case Studies:* (mustard) independent information on proven energy-saving measures and techniques and what they are achieving;

— *New Practice projects:* (light green) independent monitoring of new energy efficiency measures which do not yet enjoy a wide market;

— *Future Practice R&D support:* (purple) help to develop tomorrow's energy efficiency good practice measures.

If you would like any further information on this document, or on the Energy Efficiency Best Practice Programme, please contact the Environment and Energy Helpline on 0800 585794. Alternatively, you may contact your local service deliverer – see contact details below.

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CONTENTS

INTRODUCTION

Who this Guide is for?

This Guide is for users of bespoke (i.e. tailor-made) refrigeration systems. These include:

- refrigerated rooms (including cold and chill stores, beer cellars and temperature-controlled laboratories);
- liquid chillers;
- process cooling (e.g. food or chemicals);
- central plant systems in supermarkets.

If you have plug-in type appliances, such as small refrigerated display cases, refer to Good Practice Guide 277 *Saving money with refrigerated appliances – a guide for smaller retailers, pubs, clubs, hotels and restaurants*.

For guidance on running plug-in type appliances efficiently, see Good Practice Guide 277 *Saving money with refrigerated appliances – a guide for smaller retailers, pubs, clubs, hotels and restaurants*

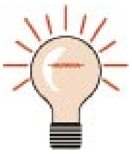
How you will benefit from reading this Guide

This Guide will show you how to:

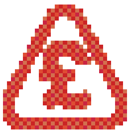
- understand the quality and cost of the refrigeration you have now;
- reduce the cost of your refrigeration;
- improve the reliability of your system;
- reduce the environmental impact of your plant.

All of this can be achieved by working effectively with contractors and consultants, and also by taking simple low-cost actions yourself.

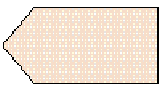
Throughout this Guide:



A lightbulb is used to highlight ideas which will help you to get the most from this Guide – and the most from your refrigeration plant.



A triangle is used to highlight information that is very important to energy efficiency.



A signpost is used to show you where you can find more detailed information about a topic elsewhere in this Guide, or in another publication.

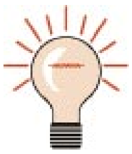
Refrigeration may be costing you much more than you think

Refrigeration energy consumption costs British industry some £300 million a year. In certain sectors – notably food & drink, and chemicals – it accounts for a significant proportion of overall site energy costs.

Sector	Typical percentage of site energy cost spent on refrigeration
Industrial production of:	
Milk and milk products	30%
Ice cream	70%
Meat, poultry and fish	50%
Frozen fruit and vegetables	70%
Chocolate and sugar confectionery	20%
Beer and other brewing	30%
Other sectors:	
Cold storage	90%
Food supermarkets	50%
Small shops with refrigerated cabinets	Over 70%
Pubs and clubs	30%

A small percentage reduction in these refrigeration energy costs can represent huge cash savings, leading to increased profits.

And what is your plant costing you through down-time, reliability and performance problems? Efficiency will help to bring all these factors under control, too.



Energy saving does not need to cost money. Most refrigeration plants can be improved to save ***up to 20%*** of their energy consumption. Much of this can be achieved at little or no cost, with paybacks for investment of well under two years being the norm.

Efficiency brings reliability

It is possible to make a reliable plant that is not very efficient. Plant designed and operated to be efficient, however, is inevitably more reliable, for two main reasons:

- the compressor does not have to work so hard in an efficient plant, which makes it less prone to breakdown and, therefore, more reliable;
- planned maintenance, an important factor for maintaining efficiency, helps improve reliability.

In addition, energy consumption can be used to give you a reasonable indication of when your plant is not operating as it should – providing an early warning of impending failure.

Reducing environmental impact

Refrigeration systems affect the environment in two ways: indirectly through the energy they consume, and directly through the effect of refrigerants if they leak to atmosphere. Making your plant as energy efficient as possible will minimise its environmental impact.

Further help is available

As you read, you may feel you wish to know more about refrigeration technology, or how design changes can improve plant efficiency. A brief introduction to refrigeration technology is included in Appendix A.

There is a wide range of information available through the Energy Efficiency Best Practice Programme. Two further Good Practice Guides are particularly useful to understand refrigeration technology better:

- Good Practice Guide 280 *Energy efficient refrigeration technology – the fundamentals* describes the basic technology and equipment for refrigeration.

- Good Practice Guide 283 *Designing energy efficient refrigeration plant,* written for designers, explains the effects of different design decisions.

Alternatively, get hold of other Guides in the Energy Efficiency Best Practice Programme refrigeration series – see the overview diagram at the front of this Guide.

1 GETTING TO KNOW YOUR PLANT

1.1 Surveying your plant

A sensible starting point for improving energy efficiency is to take a good look at your plant by conducting a survey. This should answer three questions:

- What exactly are you cooling? (Often more than you thought.)
- What plant and equipment is installed?
- How much is it costing to run?

A two-part checklist is included in this Section to help you with the survey, as well as a sheet to help you calculate the running costs for your cooling. It may be best to go round the plant with your contractor or plant manager, who can explain things and help with identification.

As you go around look for obvious problems, as described in Section 2 of this Guide, and rectify them as soon as possible.

Don't leave energy efficiency to chance – adopt a structured approach and you will save time, effort and money.

What exactly are you cooling?

Identify your cooling demands as you go around the plant with your contractor, using a copy of the checklist provided opposite. This defines two types of cooling loads.

- Product loads. These are the targets of your cooling – your products or the services you are providing.
- Parasitic loads. These are loads that are not directly related to your product or service, but still have to be cooled by the refrigeration plant (e.g. heat generated by lights or motors in cooled spaces, heat gains to refrigerant pipes and so on).

This distinction is useful because the actions you can take to minimise the two types of load are different, as described later in this Guide.

What plant and equipment is installed?

The checklist on page 6 has spaces for you to record details of the major items of plant associated with your refrigeration system. Use one checklist for each refrigeration system. This will help you to understand your plant and provide a reference as you read the rest of this Guide or discuss possible energy-saving measures with a contractor and/or consultant.

What does it cost to run?

It is worth calculating how much your plant costs to run (see Section 1.2 and the worked example on page 8). Even if your estimate is fairly crude, it will provide you with an idea of your annual costs and, hence, your scope for savings. It may also highlight some surprising performance statistics (for example, unusually high auxiliary and base loads).

Cost analysis will also indicate how much time and effort it is worth spending in trying to improve efficiency.

For most plant where attention has not recently (or ever) been focused on efficiency:

- 10% savings are easily achievable at little or no cost;
- 20% savings can be found with some effort and low cost;
- 30% savings are economically achievable with investment.

Checklist to assist in a simple plant survey

Part 1: Cooling loads

Product(s):

Type: .... Quantity .... per .... (hour, day, etc.)

Temperature: In .... Out .... (°C or °F)

Required storage temperature .... (°C or °F)

AND/OR

Room(s): Size (in m or ft): Length .... Width .... Height ....

Construction: Walls ....

Roof ....

Floor ....

Door type ....

AND

Parasitic loads:

List items that contribute heat to the refrigerant – some examples are shown. (Fans and pumps associated with the evaporator are often parasitic loads, but these are dealt with overleaf, in Part 2: Plant.)

Lights: Power ....

Uninsulated cold refrigerant pipework: Size .... Length ....

Uninsulated product pipework (for process plant): Size .... Length ....

Machinery in the cooled room: Motor rating .... kW

Operating hours .... per ....

Doors:

Details ....

Openings without door or curtains:

Details ....

Checklist to assist in a simple plant survey

Part 2: Plant

Compressors:

Number: ....

Type: Hermetic ☐ Semi-hermetic ☐ Open ☐

Rated power consumption: ☐ (W) ☐ (W) ☐ (W)

Gauges:

Number: ....

Type: Suction ☐ Discharge ☐ Oil pressure ☐

Condensers:

Number: ....

Type: Air-cooled ☐ Water-cooled ☐ Evaporative ☐

With cooling tower ☐

With mains water ☐

River water/borehole ☐

Rated power consumption: Fans (W) .... Pumps (W) ....

Receiver(s):

Number: .... *Size:* ....

Type of pressure relief device fitted: ....

Expansion device(s):

Number: ....

Type: Capillary tube ☐ Thermostatic expansion valve ☐

Electronic expansion valve ☐ Level control ☐

Evaporator(s):

Number: ....

Type: Cooling air ☐ Cooling liquid ☐

Rated power consumption: Fans (W) .... Pumps (W) ....

Refrigerant used:

Type .... Quantity ....

How is the plant room ventilated?

....

....

Other observations:

....

....

....

....

1.2 Estimating operating costs

Operating costs can most easily be measured if you have an electricity meter.

If you do have a meter, check whether it meters everything you want to measure and whether it also meters items that are not to be included in the cost estimate. You may have to make adjustments, or supplement the readings with other estimates as described below. Consider installing separate meters – it may prove worthwhile in terms of the cost, control and plant assessment benefits. Use what meter readings you have, adjusted as necessary, in steps 3 and 4.

If you do not have adequate metering, you can make a rough estimate following the guidance in steps 1 and 2 below, but bear in mind that this method may have a ±40% error (although this is better than no idea of cost at all!).

For a worked example of how to estimate running costs, see overleaf

Step 1 Estimate the instantaneous electricity consumption of the plant

Make sure that you include all of the power consumers, i.e. evaporator and condenser pumps and fans, as well as the compressor motor. Depending on how much information is available, there are two ways to estimate electricity consumption:

- By measuring the current to all of the motors and converting this into power using:

  Power (in kW) = measured current (in amps) x 1.732 x voltage x 0.85/1000;

  where: 1.732 is the square root of 3, and 0.85 is an assumed power factor.

- If no other information is available, a cruder method is to examine the nameplate of each motor and note the power rating. To get an estimate of the absorbed power, multiply this by:
  - 0.6 for the compressor;
  - 0.9 for fans and pumps.

Step 2 Convert the instantaneous consumption to energy by considering the length of time for which plant is operating

- For a more accurate figure, estimate or observe the running hours and conditions for each item of equipment, and multiply this by the power data to calculate total energy usage. Calculate usage on both a monthly and a yearly basis. For an accurate analysis of compressor energy use, you will need to allow for the fact that compressor power varies with condensing and evaporating temperatures – manufacturers' data can be useful to identify these differences, or ask your contractor or a consultant.
- For a quick analysis, multiply the power consumption calculated in step 1 by the overall system operating hours.

Step 3 Calculate total cost

Multiply the total energy consumption (kWh) by the unit energy cost (p/kWh) for your site to obtain the total cost.

Step 4 Calculate total operating costs

Add to the total cost, calculated above, any other operating costs, which could include maintenance, refrigerant top-up, routine labour, and cooling tower or condenser maintenance and water treatment.

An example calculation is given on the next page.

Example calculation of total running costs

A charge-hand fitter decides to calculate the cost of running four simple refrigeration systems. An electrician colleague measures the current to the motors of the compressors, condensers and evaporator fans using a 'clamp-on' ammeter. The factory works 60 hours/week, and the fitter estimates that the plant runs for about two-thirds of the time, i.e. 40 hours/week. The fitter's calculation for one of the four systems is set out in the table below.

Item	Amps	Estimated power (kW)	Estimated hours/week	kWh/ week	Cost/ week (at 5p/kWh)
Compressor	54.5	54.5 x 1.732 x 415 x 0.85/1000 = 33.3	40	1332	**£66.60**
Condenser fan motors	7.5	7.5 x 1.732 x 415 x 0.85/1000 = 4.58	40	183.2	**£ 9.16**
Evaporator fan motors	10.3	10.3 x 1.732 x 415 x 0.85/1000 = 6.29	40	251.6	**£12.58**
Approximate total					**£88.00**

For 52 weeks/year, this amounts to £4,500/year. Adding the other three identical plants gives an electricity cost of £22,000/year. Maintenance and other costs boost this to £25,000/year.

While this is a spot estimate, it gives a ball park figure. The exercise is worth repeating in different weather conditions.

Where 1.732 is the square root of 3, and 0.85 is an assumed power factor. If a better power factor is known, it should be used instead.

2

GOOD HOUSEKEEPING

Good housekeeping does not require special skills. It is something you and your colleagues – production operators, warehouse staff, fork-lift drivers and so on – can do. The result of good housekeeping can be a substantial reduction in running costs.

To encourage responsible behaviour it is better to focus on the positive aspects of good practice, rather than on the consequences of bad practice. Tell people the rewards of good practice.

Good housekeeping varies depending on the equipment you have. This Section divides checks and associated actions into three areas:

- around the refrigeration plant;
- in cooled rooms;
- other areas.

Good housekeeping **Page**

2.1 Good housekeeping around the refrigeration plant

Keep the condensers clean

Blocked condensers increase the condensing temperature. A 1°C increase in condensing temperature increases running costs by between 2 and 4%. The cooling capacity also drops and the required temperature may not be achieved. Get the condensers cleaned regularly and budget to replace badly corroded ones.

Make sure air entering the condensers is as cold as possible

The warmer the air onto the condenser, the higher the condensing temperature. Shade the condensers if necessary and ensure warm air is not recirculated. Remove anything obstructing the airflow.

Check the refrigerant sight glass for bubbles

Bubbles in the sight glass when the system operation is stable usually mean that the system is leaking. Remember, it is illegal to knowingly vent refrigerants. You pay for leaks twice: the system costs more to run and you have to pay for replacement refrigerant. Also, the system may not be able to provide the cooling you need. Find and repair the leaks before the system is recharged with refrigerant.

The results of refrigerant leaks are discussed more fully in Section 3: *Monitoring*, and in Good Practice Guide 178 *Cutting the cost of refrigerant leakage*

Check that the oil in the compressor sight glass(es) is at the right level (usually about halfway up the sight glass)

The compressor will be more likely to fail if the oil level is too low or too high. Find out why the level is wrong (for example, is the oil separator malfunctioning) and have the fault repaired before oil is added or taken out.

Neither refrigerant nor oil get used up during plant operation. Refrigerant can only be lost because of a leak. Oil may leak or be trapped somewhere in the system. If you need to add either, there is probably something wrong – get it checked.

Report and repair any pipework that is vibrating

Vibrating pipe work is more likely to fracture, causing a major refrigerant leak. You may need to use anti-vibration pipe mountings/arrangements and/or a length of flexible pipework. It is a good idea to get professional advice on this.

Keep the plant room as cool as possible

Running the plant hotter than necessary will reduce reliability and performance. Ventilate the plant room, preferably with an extractor fan that is switched on when the temperature gets too high. Make sure air can get out of, as well as into, the plant room.

Make sure the control settings for the plant are easy to find

There are several controllers and cut outs on refrigeration systems. These are set at commissioning, but will drift and may be re-adjusted at any time during maintenance. If the best set-points are not easy to find, the technician will choose a setting to cover most eventualities (i.e. to keep the plant running), but which is not necessarily the best one for your situation. If the settings are not displayed, get your contractor to check all of them, optimise them and put labels nearby showing what they should be.

2.2 Good housekeeping in cooled rooms

Keep the door closed as much as possible

An open door typically costs £6/hour for a freezer store and £3/hour for a chill store in lost energy. Ice around a door indicates poor sealing, with a consequent increase in the heat load. The system capacity may not be able to match the increased load, and the store temperature may increase. Stop product being left in the doorway and repair the sealing on the door. If a door has to be used regularly, fit a strip curtain and ensure that the curtains stay in good condition.

Do not stack product directly under or in front of the evaporators

Make sure product does not obstruct evaporator airflow. Impeding the airflow over the cold store will lead to a temperature increase throughout the store and consequently to the system consuming more power than necessary. Also, the store may not get down to the required temperature.

Check your evaporators defrost properly

Evaporators that operate below 0°C should be completely defrosted before ice starts to cover the fins – this may be every few hours or every few days. If the drain pan or drain lines are blocked, water will overflow onto the floor which could affect the product and create a safety hazard. When the evaporator is iced up the evaporating temperature drops – a 1°C drop in evaporating temperature increases the running costs by between 2 and 4%. The capacity also drops and the store may not get down to the required temperature. If the defrost elements are not working properly, then the frost build up on the evaporator will just get worse. Get the defrost problems sorted out. A defrost-on-demand (which initiates a defrost when needed rather than by a timer) system has been shown to reduce power consumption by 30% in some applications.

Minimise other heat sources in the cold store

Lights, fork-lift trucks, other motors, charging devices and so on in a cold store or cooled room cost you money twice – once for the electricity they consume, then again through running the refrigeration system to remove the heat they produce. Switch them off when not required. And don't forget that personnel also give off heat.

Report ice on the floor and walls of the store

Ice formation indicates that a lot of air is entering the room, bringing with it moisture, which is condensing on the evaporator and the structure. It could also indicate a defrost problem. Tell your contractor about it immediately.

Do not keep the store colder than necessary

Cold stores are often held at lower temperatures than necessary because of worries about failure. The usual excuse for this is: 'If the temperature is lower than it has to be, it gives us a few hours grace to get a contractor in when we have a problem'. In fact, having a cold store at a lower temperature than necessary makes it more likely that failure will occur! A temperature only 1°C lower than necessary is costing you between 2 and 4% more to run the plant.

2.3 Good housekeeping in other areas

Refrigeration systems have to remove heat from many sources other than the product or space you are cooling. Most of these heat gains are unavoidable, but they should always be minimised. Some common examples are:

- ***Pumps and fans*** that circulate cold air, chilled water or an anti-freeze solution, deliver most of the power they consume as heat into the cooling load. Switch them off when not required.
- ***Cold refrigerant pipes between the evaporator and compressor*** (particularly the larger suction line pipes) will pick up heat from their surroundings. These should be insulated and not run through hot areas.

3 MONITORING

Monitoring allows you to detect trends and expose developing faults. You can then correct these faults before they result in a failure costing you a lot of money. A good example of this is monitoring refrigerant leakage. Figure 1 shows how a small loss of refrigerant has minimal effect at first, but gets more severe as time progresses.

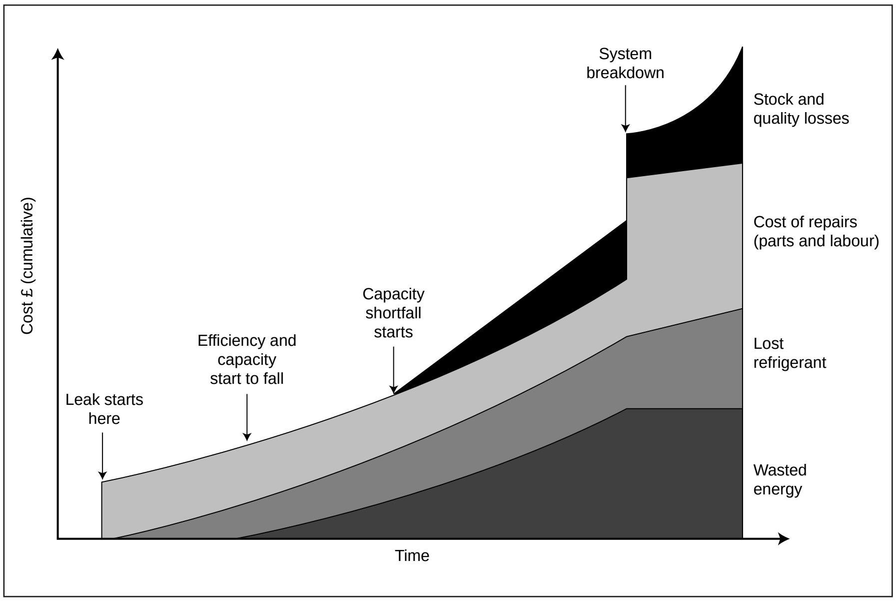


Figure 1 Example of how the cumulative effects of refrigerant leakage will cost dearly if the leakage is not monitored and repaired

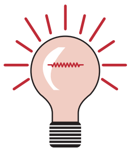
The effort you need to expend on monitoring will vary according to the size and operating cost of your plant.

3.1 Monitoring for very small plant

Even for small and simple plant, it can pay to log suction and discharge pressures, preferably daily or, at the very least, weekly. If you haven't already got gauges, have them installed. They cost just a few pounds to fit, but could save you thousands of pounds.

Keep an eye on any changes.

- A fall in suction pressure indicates a problem, for example, a refrigerant leak.
- The discharge pressure rises if the ambient temperature rises. If the discharge pressure has risen and the ambient temperature hasn't, you could have a problem such as a blocked condenser.



You should also log the temperature of the cooled space or process liquid. Take these measurements once every 24 hours at the same time of day. First thing in the morning is a good time because, if you have to call out your contractor, it will probably cost you less during the day than at night.

Maintaining a data log fulfils two objectives.

- It helps you to keep an eye on the plant. If any measurements start to change, you can call in a contractor.
- Examining the log could help the contractor diagnose the problem.

3.2 Monitoring for most plant

For most plant, more detailed monitoring may prove worthwhile. Your contractor or consultant can help you decide on the appropriate level of instrumentation for your plant, and help you to interpret the results. The log sheet overleaf shows some easy to calculate indicators that you can use to check plant performance.

In some cases, a computerised monitoring system may be justified for your plant. This system can be operated in-house or remotely. Some larger contractors offer remote monitoring services, which are particularly valuable if a refrigeration fault could lead to significant stock losses.

Possible items to include in a refrigeration plant log sheet

Basic readings

Date and time	Saturated temperature (from a pressure gauge)		Actual temperature (from a temperature gauge)		Evaporator air or liquid		Condenser air or water		Electric meter reading	Ambient temperature
	Suction (°C)	Discharge (°C)	Suction (°C)	Discharge (°C)	Inlet (°C)	Outlet (°C)	Inlet (°C)	Outlet (°C)	(kWh)	(Wet or dry bulb °C)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Other useful readings

Compressor capacity	Oil				Refrigerant		Compressor motor	
%	Pressure	Temperature	Level	Amount added†	Liquid level	Amount added†	Amps	Hours run

†This column – amount of oil or refrigerant added – ought to be blank! If not, you are wasting oil or refrigerant, risking lower reliability and probably wasting energy.

Calculation of key indicators to monitor

The following simple arithmetic calculations will give performance indicators to monitor plant performance. Numbers in brackets refer to readings from the top section of the log sheet. In each case, an increasing trend shows a deterioration.

Item	Data to use	Calculation	Result
Evaporator differential*	(6)–(1)		
Suction superheat	(3)–(1)		
Condenser differential*	(7)–(2)		
Discharge superheat	(4)–(2)		
Ambient temperature differential*	(2)–(10)		
Electricity consumed*	(9)–last reading		

Not every reading will be relevant to every site. Having referred to the text in this Guide, choose those that are applicable to your plant. All the performance indicators you can calculate are best recorded on a graph (especially those marked with an asterisk *) to identify adverse trends. All the calculations and graphs are easily done on a computer spreadsheet.

4

MAINTENANCE

Maintenance should be a routine event, like servicing a car. Regular maintenance will save you money because it will keep your plant operating efficiently, and reduce the risk of unscheduled call-outs arising with all their associated costs.

The best contractors will be able to prove a good track record through references and convincing answers to your questions.

Maintenance	Page

4.1 Choosing a maintenance contractor

Personal recommendation is the best way to find a consultant or contractor. Failing that, the Institute of Refrigeration (IoR) and British Refrigeration Association (BRA) both have lists of suitably qualified consultants and contractors. Other sources include the *RAC Magazine Yearbook*.

For contact details of the IoR, BRA and RAC, see Appendix B

There is a series of questions you could ask potential maintenance contractors. The way the contractor answers – and justifies their answers – will give you valuable clues as to their competence and awareness of the relevant issues.

- ***What sort of plants have they been involved with previously?*** Look for plants with requirements that seem similar to your own. Ask for contacts as references and follow them up.
- ***What level of operating support will be available?*** How quickly do they respond to call-outs? Are their technicians located at a reasonable distance from your plant for call-outs?
- ***What service and maintenance procedures can they show you that are relevant to your plant?*** A good contractor will be able to show you a range of appropriate, pre-set procedures that they follow. One advantage of getting competitive quotes is that you can compare exactly what each tenderer is proposing to do – and you will have a reference point to check against later.
- ***What is their call-out ratio?*** That is, how many call-outs do they get per system they service? If they can provide this information, it indicates that they control their sites well, irrespective of the size of the company. If the ratio is one or two per year, they are looking after their plants well. Higher numbers may indicate poor service, although there could be other reasons, which they will no doubt explain.
- ***What would happen when your regular maintenance person is on holiday or off sick?*** This can make a vital difference to call out times (especially in hot weather, which coincides with school holidays).
- ***What do they think of your plant, and why?*** This will indicate how well they have assessed your plant, give some idea of how it has been looked after in the past, and perhaps suggest if they are likely to do any better.

- ***Have they read the series of Energy Efficiency Best Practice Programme refrigeration Guides?*** Good Practice Guide 282 *Service and maintenance for efficient refrigeration plant – a guide for technicians and contractors* is particularly relevant. A negative answer is not necessarily bad in itself, but the question will highlight your interest in energy efficiency, and from their answer you may be able to tell how important energy efficiency is to them.

- ***Are all the technicians that might work on your site trained in refrigerant handling skills, and are they also provided with the tools they need to do the job safely and effectively?*** You should insist that all technicians have a suitable qualification such as City and Guilds 2078 or Construction Industry Training Board (CITB) Refrigerants Handling assessment.

Further information on these issues is contained in Good Practice Guide 282 *Service and maintenance for efficient refrigeration plant – a guide for technicians and contractors*

- ***Do they have any suggestions for improving the efficiency and reliability of your plant?*** The precise answer is not important. Some will wonder why you ask, others will make useful observations and tell you the cost consequences. Again, this will show their general attitude to energy efficiency and their awareness of the major issues.

- ***Do they have a quality policy?*** Compliance with the quality management standard ISO 9000 would be an advantage.

- ***Do they have safety and environmental policies?*** For example, are they members of a recognised safety organisation, and do they operate to the environmental standard ISO 14000? Can they provide evidence of formal training in safety and environmental management? Safety training is especially important for ammonia plant.

The best contractors will be able to prove a good track record through references, and give convincing answers to the questions above.

Once you have selected a maintenance contractor, you can decide on the most appropriate form of contract.

4.2 Types of maintenance contract

The standard formats are:

- ***Inspection maintenance.*** This type of contract typically provides one preventive maintenance visit per year. The number of visits appropriate to your plant should be agreed with the contractor.

- ***Full inspection.*** The number of preventive maintenance visits is agreed. In addition, you will not be charged for any labour used to carry out repairs during normal working hours.

- ***Semi-comprehensive.*** The end user agrees on the number of inspections per year. All breakdown labour is included in the price, as is the cost of all consumable materials. The replacement of major items of equipment, for instance compressors, would not be included in this premium.

- ***Comprehensive.*** As with other contracts, the number of preventive maintenance visits is subject to negotiation. Under the terms of this contract, however, the end user is not liable for the cost of any further maintenance expenses throughout the period of the agreement.

In addition, there are *specialised contracts* that are formulated to take into consideration the particular requirements of some applications. For example, some plant may be switched off and isolated for extensive periods, and will thus require a specialised pre-start inspection.

Whichever you choose, remember that the maintenance contract should take into account the refrigeration component manufacturer's recommendations, and be designed around each individual plant.

When considering the duration of the contract, bear in mind that contractors who know that they are almost certain to lose the contract within a year have very little incentive to act in the long-term best interests of you or your plant – they will probably just spend the minimum possible time on site to keep it going.

4.3 Maintenance schedules

Maintenance work will depend on the size and complexity of the plant, as well as on the components used. As a minimum, make sure the contractor checks:

- **Compressors** — Oil level.
  Suction and discharge pressures and temperatures.
- **Condensers** — Fans and pumps are working.
  Fan guards are safe and secure.
  Condenser is not blocked; clean condenser if necessary.
- **Gauges** — For accuracy.
- **Receiver** — If there is a liquid level sight glass or gauge, that it contains the right amount of refrigerant.
- **Evaporator** — As for condensers, plus the degree of frost build up.
  Liquid line sight glass to see that it contains the right amount of refrigerant.
- **Safety and efficiency** — All safety controls.
  Control switches to ensure that they have not drifted from the optimum set-point.
  Suction superheat to confirm that expansion valves are operating correctly.
  Pressure vessels (e.g. liquid receivers) may need a written scheme of inspection to be carried out by a competent person (see the box on page 18).
- **Others** — No untoward vibration on any part of the system.
  Pipework insulation is still in good condition.
  For leaks (European Union legislation on Ozone Depleting Substances planned for 2000 is likely to require annual checks to be conducted on all systems containing over 3 kg of refrigerant).
  Insulation for damage, if you have a cold store or cabinet.
  Cold store safety door releases.

Condenser cleaning and leak detection are probably the most worthwhile jobs that a service contractor can do because they have the most effect on plant performance. How frequently the condenser needs to be cleaned depends on local environmental conditions. For example, a site within a mile of a factory that emits a lot of dust might clean its condensers every two weeks, whereas another site might only need to clean its condensers once a year.

A little maintenance makes a big difference

The refrigeration plant at a cheese factory was experiencing high condensing pressures, leading to increased energy usage and higher fuel bills. To lower the pressures, maintenance staff ordered a new, air-cooled condenser. Prior to installation of the new unit, the existing condenser was cleaned. Once cleaned the old condenser was able to handle all the plant's heat rejection, and the new condenser was not required.

4.4 Monitoring your contractor

It is sensible to check that the agreed maintenance is being carried out in accordance with the specified procedures. Get your contractor to set up a maintenance log that is signed by the technician after every visit. The log should include details of any refrigerant and/or oil added, and the name of the technician who carried out the work. **Insist that it is legible.** If something goes wrong, the log will provide a clear record for investigation.

Ask the contractor to tell you what the plant has cost you in terms of maintenance each year. Ensure they include costs covered under the maintenance contract, plus any components replaced outside of the contract. This will help you to plan capital cost replacement when it is appropriate.

You can also employ a consultant to do a random audit on the maintenance of your plant, or you can do it yourself.

The Environment and Energy Helpline on 0800 585794 will be able to provide you with further details

Statutory requirements

The UK Pressure Systems and Transportable Gas Containers Regulations, 1989, apply to all refrigeration systems with a compressor drive motor of over 25 kW. These regulations place a duty on the 'user' to ensure that the system is operated safely. The user must appoint a 'competent person' to draw up a 'written scheme for examination' of the plant, and regularly inspect the plant using this scheme. If you are not familiar with this legislation, obtain the relevant Health and Safety Executive (HSE) guidance notes, or speak to your contractor, consultant and/or insurer to ensure that you comply.

Prevention is better than cure

Two years ago, Birmingham-based Bass Leisure began a review of the cooling in its cellars following a series of breakdowns. It discovered that the level of preventive maintenance was inadequate.

The company reviewed its maintenance requirements and placed contracts with seven service contractors. These contracts explicitly called for planned preventive maintenance. Bass also appointed a third-party facilities management organisation to monitor and record the performance of the service contractors.

5

CONTROL

A good basic rule is to keep your control system as simple as possible. Getting controls and their settings right is a big step towards making your plant operate as efficiently as possible. The following guidance can help you achieve this.

5.1 Settings

Get your maintenance contractor to check that all the controls attached to your refrigeration plant are working, and that their set-points are correct, especially the thermostat set-point. ‘Correct’ means not just a safe setting that would be suitable for any plant, but one that will result in the best energy efficiency for your plant without compromising reliability. Get the contractor to note the correct settings on the plant log, and mark them on a label attached to the plant so that the same settings can be used in future.

Wherever possible, mark the normal readings on gauges so that you can see instantly when a piece of equipment is not working as expected.

5.2 Controls

There are a number of low-cost controls that can be added to plant with good results. Your contractor can advise you which of the following are applicable to your plant.

- Automatic controls can switch off the refrigeration plant and/or lights when they are not required.

- Automatic switches or variable speed drives (VSDs) can be fitted to fans and pumps that circulate cold air, chilled water and anti-freeze solutions. Paybacks of one year or less can be achieved in practice.

- For plants with multiple condensers or cooling towers, modern microprocessors are a better option than traditional pressure switches. The microprocessors allow you to obtain the minimum condensing temperature possible for your plant, to take advantage of cost savings in cooler weather. Head pressure control using traditional pressure switches only make the full capacity of the condenser system available in the warmest weather, so the condensing temperature is usually higher than it needs to be.

- Effective sequence control where your plant has several compressors. Poor settings or control design can lead to several compressors operating at part load simultaneously, which increases wear and tear and energy consumption.

- Electronic and balanced port expansion valves. Most condenser systems are thermostatically controlled to maintain a minimum condensing temperature. Using these valves allows lower settings to be used, and can make thermostatic controls redundant.

See Good Practice Case Studies 89, *Variable speed drives on cooling water pumps*, and 124, *Variable speed drives on secondary refrigerant pumps*

For further information, see General Information Leaflet 52, *Selecting and running compressors for maximum efficiency*

Good Practice Case Study 302, *Improving refrigeration performance using electronic expansion valves*, shows how electronic expansion valves were fitted to a small cold store at a cost of £3,000, with a payback of 1.4 years

The value of installing the correct controls

A milk processing factory operated a chilled water plant on water temperature control, with a back pressure valve installed in a common suction main running to six large reciprocating compressors. As a consequence, all six machines ran continuously at low suction pressures. This meant the compressors had to work harder and, therefore, consumed more energy. When the control system was updated by the installation of a programmable logic controller, the back pressure valve was removed. Subsequently, the compressors operated with higher suction pressures and the number of machines required to run was, therefore, reduced. Energy cost savings amounted to over £60,000/year, and the cost of upgrade was recovered in just under six months.

6

CAPITAL EXPENDITURE

Now is the time to consider whether it is appropriate for you to invest capital in more ambitious changes.

Rather than rush ahead with single, apparently attractive ideas, take a rational and global look at them and develop an **opportunity list**. It is useful to group ideas into categories:

- ***Cooling load*** opportunities relate to the process being cooled (rather than to the refrigeration plant itself). It is often possible to eliminate or reduce a cooling load, which can have a tremendous impact on the running costs of refrigeration plant. At the design stage, reducing the load should also reduce the capital cost of a refrigeration system. Careful appraisal of cooling loads is a critical part of identifying refrigeration efficiency opportunities. Investigate the possible use of free cooling or pre-cooling.

- Once the cooling load has been minimised, appraise the **system design**. This encompasses issues such as the way the refrigeration system is configured, and how the plant responds to part load operating conditions, including loading and ambient temperature.

- ***Component design*** opportunities relate to the detailed design and selection of individual components within the chosen system design (condensers, expansion valves, etc.).

Splitting the savings opportunities in this way will help you to see how they inter-relate. It is clear, for example, that a decrease in cooling load will reduce the demand on the refrigeration plant and its auxiliaries. This can either increase or decrease the value of the other opportunities. It is, therefore, often sensible to appraise cooling loads first, then re-evaluate the other categories in turn, as they may have become more or less attractive.

In general, your service/maintenance contractor will be able to provide you with costs for these projects, and tell you how much will be saved. They can also contribute ideas, and help with measuring and monitoring the savings.

When you are requesting finance for your projects from your Board or bank manager, Good Practice Guide 236 *Refrigeration efficiency investment: putting together a persuasive case* may be helpful. If you are considering capital investments on new plant, or modifying or extending your system, Good Practice Guide 278 *Purchasing efficient refrigeration – the value for money option* will also be useful.

Good Practice Guides 236 *Refrigeration efficiency investment: putting together a persuasive case* and 278 *Purchasing efficient refrigeration – the value for money option* may be helpful

Contact the Environment and Energy Helpline on 0800 585794 for copies of these publications

Examples of how capital investment can be applied

The series of Good Practice Case Studies on refrigeration gives examples of good investments in energy efficiency.

- Case Study 89 *Variable speed drives on cooling water pumps* shows how Manchester Airport fitted 10 variable speed drives to motors between 7.5 and 37 kW. Paybacks as low as one year were achieved.
- Case Study 92 *Automatic air purging on a cold store refrigeration plant* shows how air can enter refrigeration systems that operate with part of the circuit under vacuum, elevating condensing temperatures. Based on the experiences of Exel Logistics, the case study shows how, even though the company manually purged this air from its plant, adding an automatic purger led to savings in both energy and maintenance. The payback was just 10 months.
- Case Study 230 *A new refrigeration system for a small cold store* describes how Doble Quality Foods needed to replace its cold store refrigeration system and thought carefully about the new plant's operating costs. The Case Study explains the steps the company took, which are also applicable where parts of a system need to be replaced. Doble spent £30,000 on the new plant, £4,000 more than for a less efficient system, but achieved a payback of nine months on this extra investment.
- Case Studies 223 and 350 show the proven advantages of fitting night blinds and strip curtains on refrigerated display cabinets.
- Case Study 248 *Strategy for major cooling plant replacement* shows how Ind Coope Burton Brewery (now part of Bass Brewers) took energy costs into consideration when planning its new installation and saved £160,000/year, 30% of its previous costs. The project was completed within the original budget.
- Case Study 301 *Use of larger condensers to improve refrigeration efficiency* details how, when new condensers were required at one of its plants, Exel Logistics bought larger ones than standard designs. The payback on the extra cost of £5,000 was two years.
- Case Study 302 *Improving refrigeration performance using electronic expansion valves* provides details of how electronic expansion valves were added to the cold store at Doble Quality Foods (see Case Study 230), making further savings and achieving a payback of 1.4 years.

A BRIEF INTRODUCTION TO REFRIGERATION TECHNOLOGY

A

Refrigeration exists to cool a product or maintain it at a lower temperature than its surroundings. A refrigeration system uses a refrigerant to transfer heat from a fluid or product to be cooled to ambient air or water.

A simple refrigeration system comprises:

- An **evaporator** in which the refrigerant boils (or evaporates) at a temperature lower than the product which is to be cooled. The evaporating refrigerant absorbs heat from the product as it boils, thus cooling the product.
- A **compressor** which compresses the gas generated in the evaporator.
- A **condenser** in which the high pressure gas pumped by the compressor is liquefied (or condensed). During this process the refrigerant rejects heat, usually to ambient air or water.
- An **expansion device** which drops the pressure of the condensed liquid back down to the pressure of the evaporator.

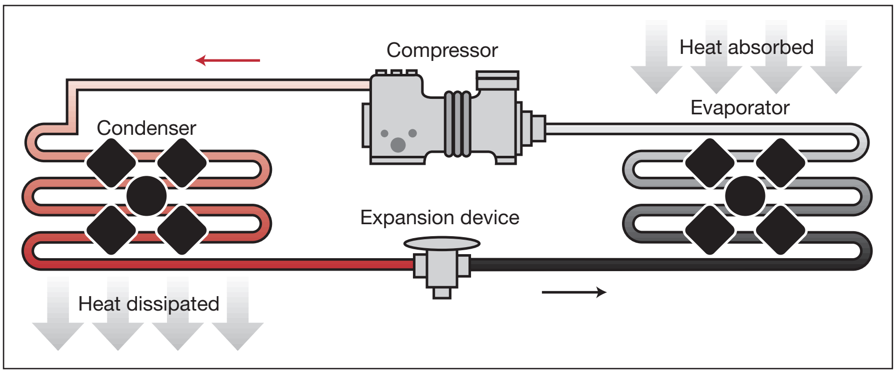


Figure 2 Schematic diagram of a simple refrigeration system

- A set of controls that might include:
  - A **thermostat** that switches the refrigeration system off when the required temperature has been reached, and switches the system on again when the product has reached its upper temperature limit. The differential between off and on must not be low enough to cycle the refrigeration compressor rapidly.
  - **Pressure switches** for system protection. A high-pressure cut-out switch turns the compressor off when the pressure on the high pressure side of the system rises too high. A low-pressure cut-out shuts off the compressor if the suction pressure drops below a set limit (for example, due to loss of refrigerant from the system).
  - **Compressor motor protection devices** that switch off the compressor if the electrical current rises too high.

If you want to look deeper into the technicalities of refrigeration systems, get a copy of Good Practice Guide 280 *Energy efficient refrigeration technology – the fundamentals*

The amount of heat a refrigeration system removes is measured in watts (W). The extraction rate will depend on the size of the system and the conditions under which it is operating.

To drive the system, energy, usually in the form of electrical power, has to be put in to the compressor's motor and to other motors for pumps, fans, etc. This is also measured in watts. The system is operating at optimum efficiency when the minimum input power achieves the maximum heat extraction. The expression used to describe the efficiency of a refrigeration system is the coefficient of system performance (COSP).

$$\text{COSP} = \frac{\text{Refrigeration capacity (watts)}}{\text{Total system power input (watts)}}$$

Do not confuse COSP with the commonly quoted COP (coefficient of performance) which relates to the power consumed by the compressor alone.

B

SOURCES OF FURTHER INFORMATION

The following are a list of useful addresses and publications for the Refrigeration and Air Conditioning industry.

Environment and Energy Helpline
Tel: 0800 585794
E-mail: etbppenvhelp@aeat.co.uk
Internet Home Page: http://www.energy-efficiency.gov.uk

A free advisory service for UK businesses on environmental and energy efficiency issues provided by the Government. Also able to advise on the range of free information available via the Government's Energy Efficiency Best Practice Programme and Environmental Technology Best Practice Programme. A full list of refrigeration publications is available through the Environment and Energy Helpline.

British Refrigeration Association (BRA)
Henley Road, Medmenham, Marlow, Bucks SL7 2ER
Tel: 01491 578674 Fax: 01491 575024
Internet Home Page: http://www.feta.co.uk

The BRA has section for designers, users, manufacturers, distributors and installers of components and systems in the refrigeration industry. It also has an active interest in training. The BRA publishes single page Fact Finder sheets dealing with topical issues in the industry and recommended procedures concerning specific factors in the design and operation of refrigeration systems and companies. It also publishes Guideline methods of calculating TEWI.

Institute of Refrigeration (IoR)
Kelvin House, 76 Mill Lane, Carshalton, Surrey SM5 2JR
Tel: 020 8647 7033 Fax: 020 8773 0165
E-mail: ior@ior.co.uk
Internet Home Page: http://www.lor.org.uk

The IoR is the professional body of the refrigeration industry. It provides information to the industry through published papers, seminars, codes of practice etc.

TRADE JOURNALS

There are a number of publications dealing with the refrigeration and air conditioning industry.

Refrigeration and Air Conditioning (RAC)
Published by:
EMAP Business Communications, 19th Floor, Leon House, 233 High Street, Croydon CR0 9XT
Tel: 020 8277 5412 Fax: 020 8277 5434
Email: AndrewB@Trenton.emap.co.uk (for the editor).

AC&R News
Published by:
Faversham House Group, 232a Addington Road, South Croydon, Surrey CR2 8LE
Tel: 020 8651 7100 Fax: 020 8651 7117
Email: paul@fav-house.com (for the editor).

ACR Today
Published by:
Battlepress Ltd, Nithsdale House, 159 Cambridge Street, Aylesbury, Bucks HP20 1BQ
Tel: 01296 425151 Fax: 01296 435091
Email: info@aydee.com

The Government's Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

For buildings-related topics please contact:
Enquiries Bureau
BRECSU
Building Research Establishment
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

For industrial and transport topics please contact:
Energy Efficiency Enquiries Bureau
ETSU
Harwell, Didcot, Oxfordshire,
OX11 0RA
Fax 01235 433066
Helpline Tel 0800 585794
Helpline E-mail etbppenvhelp@aeat.co.uk

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.

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